Appendix C

Program Drivers: Materials Destined for Geologic Disposal

Spent nuclear fuel generated by commercial nuclear reactors constitutes by far the largest stock of nuclear materials destined for geologic disposal. But a repository is also essential to the disposition of an array of other nuclear materials that are managed by the Department of Energy. This appendix summarizes current planning assumptions about how the disposal capacity of the repository would be allocated among all waste forms. It also consolidates some historical, technical, and policy information about these DOE-managed nuclear materials. And it reports current and projected inventories of those materials and of commercial spent nuclear fuel.

Allocation of Repository Capacity: Current Planning Assumptions

Projected inventories and the statutory limit on the quantity of waste emplaced

The Nuclear Waste Policy Act of 1982 places a statutory limit of 70,000 metric tons heavy metal (MTHM) on the quantity of waste that can be emplaced in the first repository until a second repository is in operation. The 1987 Amendments Act terminated all work on a second repository and required the Secretary to report to the President and to Congress on or after January 1, 2007, but not later than January 1, 2010, on the need for a second repository. OCRWM's current projections of waste inventories extend through the year 2035, a date beyond the expiration of all currently held operating licenses for commercial reactors and the last year for which DOE's Office of Environmental Management believes it can reliably project its operations for planning purposes. The total inventory of commercial spent nuclear fuel and DOE-managed nuclear materials requiring geologic disposal, projected through 2035, exceeds 70,000 MTHM.

The OCRWM planning basis allocates 7,000 MTHM of the 70,000-MTHM statutory limit to DOE-managed nuclear materials. Of that 7,000 MTHM, two-thirds would be high-level radioactive waste solidified in glass, including immobilized plutonium waste forms; one-third would be DOE and naval spent nuclear fuel.

For planning purposes, we analyze a range of design and operational capabilities. The lower bound is consistent with the 70,000-MTHM statutory limit. The upper bound is based on projections of the total quantity of spent nuclear fuel and high-level radioactive waste requiring disposal. Analyses of the upper bound enable us to evaluate the actual physical capability of a repository at the Yucca Mountain site to safely isolate these wastes; these analyses support site characterization, design work, preparation of the environmental impact statement, preparation of a license application, and definition of repository operational needs. The analyses could also support a decision on the need for a second repository.

OCRWM's current policy, documented in the Civilian Radioactive Waste Management System Requirements Document, Revision 5, is that repository design accommodate the total quantity of spent nuclear fuel and high-level radioactive waste projected to require disposal. However, OCRWM would comply with any future statutory, regulatory, or license limitations on the amount of waste to be emplaced in the repository.

Waste emplacement strategies

Because waste packages containing commercial spent nuclear fuel give off a lot of heat, under current planning they would be spaced far apart in the emplacement drifts. Waste packages containing non-commercial wastes, which give off relatively little heat, would be placed between them. This design strategy optimizes the use of the area that must be excavated, and thus minimizes cost. Our design strategy also employs the concept of co-disposal of high-level radioactive waste and some types of DOE spent nuclear fuel. The concept entails placing a canister of DOE spent nuclear fuel into the center cavity of a disposal container that holds five canisters of high-level radioactive waste. This configuration would minimize the number of disposal containers required, and thus their total cost, while satisfying requirements for criticality control.

Quantities and comparisons

The table below, based on data that support the viability assessment, identifies quantities of materials requiring geologic disposal that are projected through 2035 and quantities allocated to the first repository for planning purposes. The map on page 12 shows the location of these materials.

In the table, quantities of spent nuclear fuel are expressed in metric tons heavy metal (MTHM), a conventional and useful comparison among similar types of spent nuclear fuel. However, because fuel matrix and enrichment levels vary among fuels, MTHM can be a misleading measure when used to compare different types of spent nuclear fuel. For example, naval spent nuclear fuel comprises 65 MTHM and occupies a volume of 888 cubic meters; spent nuclear fuel from DOE's N-reactor at Hanford comprises 2,102 MTHM but occupies a volume of 206 cubic meters. Comparisons based on MTHM become particularly misleading when spent nuclear fuel is compared with high-level radioactive waste, because the latter, which derives from reprocessing spent nuclear fuel, has had most of its heavy metal removed. Consequently, for the purposes of repository design and planning operations, quantities of high-level radioactive waste are expressed in terms of canisters of vitrified high-level radioactive waste. The table below also uses canisters as a measure of quantities of high-level radioactive waste. The table and accompanying pie charts use disposal containers as a unit of measure to facilitate comparisons of quantities of all waste forms.

In the table below, values for plutonium waste forms are included in commercial spent nuclear fuel and high-level radioactive waste. This reflects the Department's current planning assumptions for disposition of surplus weapons-usable plutonium. Of the total 50 metric tons of surplus plutonium, 32 would be incorporated into a mixed oxide fuel that would be burned in commercial reactors, becoming part of the commercial spent nuclear fuel inventory sent to a repository. The remaining 18 metric tons would be disposed of as a ceramic-based waste form; that waste form would be placed in canisters that would then

be filled with vitrified high-level radioactive waste. The resulting can-in-canisters would be included in the inventory for high-level radioactive waste.

DOE-Managed Nuclear Materials: Background and Current Planning Assumptions

The decision path to disposal of DOE-managed nuclear materials

Stored at multiple sites, DOE-managed nuclear materials take forms that vary widely. Some materials have not yet been converted to final disposal forms. While current planning assumes that many of these materials will be disposed of in a repository, the Department's plans are still evolving. The impacts on the repository system of materials identified for disposal were evaluated in the total system performance assessment that supported the viability assessment. That performance assessment also supports the environmental impact statement (EIS) that will evaluate the potential impacts of transporting and disposing

Quantities of Nuclear Materials Destined for Geologic Disposal

Waste Type	Quantities Projected Through 2035[1]	Number of Disposal Containers Needed for Total Quantity of Waste Projected Through 2035	Planning Allocation for First Repository under Statutory 70,000-MTHM Limit	Number of Disposal Containers Needed for 70,000-MTHM Allocation for First Repository
Commercial spent nuclear fuel (SNF)[2]	87,000 MTHM	10,455	63,000 MTHM	7,642
Commercial high-level radioactive waste (HLW)	300 canisters	HLW-only: 2652	300 canisters	HLW-only: 322
DOE HLW	19,300 canisters	SNF-only: 950	972 canisters	SNF-only: 907
Can-in Canister HLW[3]	635 canisters	Co-disposal: 1,349	635 canisters	Co-disposal: 1,344
DOE SNF[4]	2,435 MTHM		2,271 MTHM	
Naval SNF	65 MTHM	300	62 MTHM	285

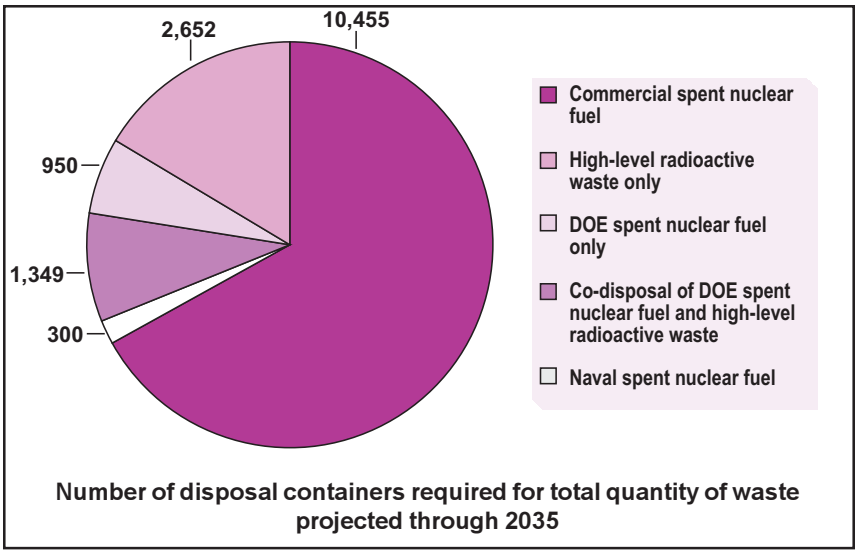
Source of data for this table: *Basis for the VA and TSLCC Cost Estimate Operational Waste Stream*, June 1998, CRWMS M&O: A80-01717-1710-0002, Rev. 00

[1]Please see the text above for an explanation of why quantities of high-level radioactive waste are expressed in canisters.

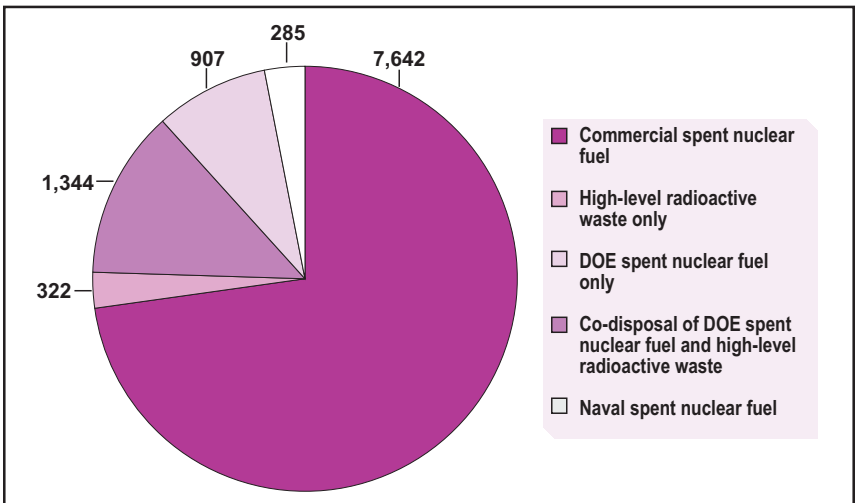
[2]Figures for commercial spent nuclear fuel assume no new reactor construction and no license extensions or renewals; they include mixed-oxide spent nuclear fuel fabricated with surplus weapons-usable plutonium.

[3]*Can-in-canister* refers to surplus weapons-usable plutonium that has been immobilized and placed in a canister with vitrified high-level radioactive waste.

[4]Inventory will include foreign research reactor fuel returned to the United States.



Number of disposal containers required for total quantity of waste projected through 2035



Number of disposal containers required for first repository 70,000-MTHM allocation

of materials destined for the repository. Any recommendation of a site by the Secretary to the President must be accompanied by the final EIS and a discussion of data obtained through site characterization relating to the safety of the site, preliminary comments of the NRC, views of the Governor and legislature of Nevada, and other pertinent information. New total system performance assessment analyses will support the Secretary's decision on a site recommendation to the President and would support a license application to the NRC. Future total system performance assessments will also evaluate the impacts of disposal of DOE-managed nuclear materials.

The text below presents some background information on major inventories of material destined for geologic disposal. Quantities cited are subject to change as planning assumptions change and programmatic decisions are made and carried out. Sources of data are those cited for the tables above.

High-level radioactive waste

High-level radioactive waste inventories resulted from reprocessing spent nuclear fuel to recover plutonium and uranium. DOE originally intended to reprocess most of its spent nuclear fuel, and reprocessing began at a number of Federal sites as early as the 1940s. In 1985, when the President determined that high-level radioactive waste resulting from atomic energy defense activities could be

disposed of in the civilian repository, DOE and naval spent nuclear fuel were being still being reprocessed, and reprocessing continued until 1992, when the Administration discontinued the practice.

Wastes from reprocessing are stored as aqueous solutions, sludges, and calcines at DOE's Idaho National Engineering and Environmental Laboratory (INEEL), the Hanford Site in Washington State, and the Savannah River Site in South Carolina. These wastes would be accepted at the repository only in solid form, and the Department plans to vitrify them as borosilicate glass canisters. The canisters will be safely stored near the vitrification site until they are transported to the repository for disposal. At the Savannah River site, vitrification has begun. A total of over 19,300 canisters of high-level radioactive waste are projected through 2035. In addition, the West Valley Demonstration Project in New York State, a facility now managed by DOE, is vitrifying high-level radioactive waste that resulted from commercial reprocessing of spent nuclear fuel. Approximately 300 canisters of vitrified waste will be produced.

DOE spent nuclear fuel

When reprocessing was discontinued in 1992, the remaining intact spent nuclear fuel was placed in storage pending ultimate disposition. In 1995, concluding the development of a programmatic environmental impact statement that evaluated options for disposal, DOE issued a Record of Decision stating its intent to dispose of its spent nuclear fuel in a geologic repository and to store it regionally prior to disposal, largely on the basis of fuel composition. A 1996 Record of Decision for foreign research reactor spent nuclear fuel determined that most of this special type of fuel would be stored at the Savannah River Site, with the remainder stored at INEEL.

Through the year 2035, the total inventory of DOE spent nuclear fuel is projected to be approximately 2,435 MTHM.

- *Hanford Site*. Most of the DOE inventory of spent nuclear fuel, 2,133 MTHM, is now at the Hanford Site in Washington State, where spent nuclear fuel was generated in the N-reactor for use in the weapons program. The Department plans to place this spent nuclear fuel, which is metallic-based, in dry storage at that site.

- *Savannah River Site.* Spent nuclear fuel from production reactors has been stored at this South Carolina site, and some of it has been converted to high-level radioactive waste for disposal. The 41 MTHM of spent nuclear fuel now in storage there includes remaining unprocessed production reactor fuel and some domestic research reactor fuel. This inventory number is projected to remain unchanged through the year 2035. The Department has also designated this site for storage of aluminum-clad spent nuclear fuel from domestic and foreign research reactors. The uranium in foreign reactor fuel was originally exported by the U.S. Government under the Atoms for Peace Program. In keeping with nuclear nonproliferation policies, foreign research reactor fuel is being returned to this country and placed under DOE management. Up to 16 MTHM is projected to be returned, of which approximately 15 MTHM will be stored at the Savannah River Site.

- *Idaho National Engineering and Environmental Laboratory*. The DOE spent nuclear fuel now stored at this site originated in activities to promote the peaceful uses of atomic energy, beginning

with the passage of the Atomic Energy Act of 1954. (The naval spent nuclear fuel stored at this site is discussed below.) The approximately 193-MTHM inventory, projected to remain essentially unchanged through 2035, includes spent nuclear fuel from demonstration reactors, from research and development activities, and from activities to demonstrate storage technologies and characterization for disposal. The research reactor fuel stored at this site is not aluminum-based; it will include 1.0 MTHM of foreign research reactor spent nuclear fuel. A 1996 Departmental environmental impact statement and Record of Decision provided for storage of this fuel at INEEL. Debris from the Three Mile Island reactor is also stored at this site. Under a consent agreement between DOE, the Navy, and the State of Idaho, all spent nuclear fuel stored in that State must be removed by January 1, 2035.

The total projected inventory of DOE spent nuclear fuel includes approximately 44 MTHM stored at other sites, including some commercially irradiated spent nuclear fuel now managed by DOE. This inventory is projected to rise to approximately 50 MTHM by the year 2035. In addition to the quantities of DOE-managed spent nuclear fuel discussed above, 60 metric tons of sodium-bonded spent nuclear fuel, most of it stored at INEEL and Argonne National Laboratory-West, are being evaluated to determine whether it requires treatment to make it suitable for disposal. The Department is preparing an environmental impact statement for proposed disposition of this spent nuclear fuel, as required by the National Environmental Policy Act. If the fuel is treated, it could be disposed of as high-level radioactive waste.

Naval spent nuclear fuel

The Department of the Navy fabricates its own nuclear fuel for its nuclear-powered vessels using uranium-235 leased from DOE. For many years, naval spent nuclear fuel was shipped to the Idaho Chemical Processing Plant, where DOE reprocessed it to recover the uranium. Following DOE's termination of reprocessing in 1992, an agreement was reached in October 1995 between the Federal Government and the State of Idaho to allow the temporary storage of naval spent nuclear fuel at INEEL. Under the consent agreement, naval spent nuclear fuel will be among the first shipments to a repository. In 1996, the Navy issued a Record of Decision stating that it would store its spent nuclear fuel in dual-purpose canisters in Idaho prior to shipping it to a geologic repository for disposal. The inventory now consists of approximately 14 MTHM; by 2035 it is projected to total approximately 65 MTHM.

Surplus weapons-grade plutonium

Recovered primarily from dismantled nuclear warheads, most surplus weapons-usable plutonium is stored as weapons components at the DOE Plant site in Texas. Approximately 50 metric tons will be dispositioned to support national nonproliferation objectives.

In January 1997, the Department published a Record of Decision stating that it was considering a dual-track strategy for dispositioning of its surplus weapons-usable plutonium and that it intended to dispose of the final waste forms in the geologic repository under the Nuclear Waste Policy Act of 1982, as amended. The DOE Draft Environmental Impact Statement on Surplus Plutonium Disposition issued in July 1998 identifies an option in which 18 metric tons of this plutonium would be immobilized in a ceramic waste

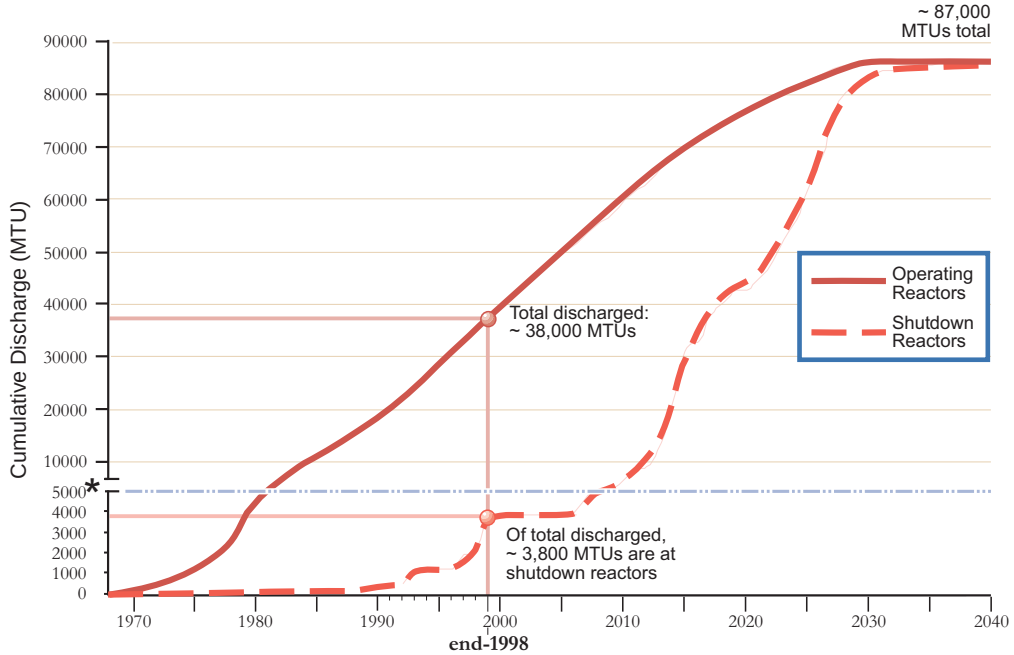
form and placed in small stainless steel cans. The cans would be arrayed in a canister that would be filled with molten glass mixed with high-level radioactive waste. The inclusion of high-level radioactive waste would increase the level of radioactivity of the resultant waste form so that it would be high enough to meet the spent fuel standard for safeguards and security requirements. (NRC policy requires that no waste form emplaced in a repository be more attractive from a nonproliferation standpoint than commercial spent fuel.) The waste forms would be stored at a high-level radioactive waste storage site to be designated.

The remaining 32 metric tons of plutonium would be converted to a mixed oxide fuel that would be burned in commercial light water reactors; the resulting spent nuclear fuel would be stored at the reactor sites until it was transported to the repository for disposal.

Commercial Spent Nuclear Fuel: Locations and Current and Projected Inventories

By December 1998, spent nuclear fuel containing approximately 38,000 metric tons uranium (MTU) was stored at 72 commercial power reactor sites and one storage site. Those sites are located in 33 States. Of the 118 reactors at these 72 sites, 14 are shut down. Ten operating sites have added on-site dry storage to supplement their pool-storage capacity; others are approaching full pool capacity and will need additional storage.

Based on current projections, by 2035, when the last of the existing 118 commercial power reactors will have completed its initial 40-year license period, spent nuclear fuel containing a total of about 87,000 MTU will have been generated.



*Note change in vertical scale below 5,000 MTU

Source: OCRWM projections based on historical data from EIA, assuming no new orders or lifetime extensions

Commercial Spent Fuel Inventories Through 2035

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